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(71) Applicant(s) University Court of Napier University (Incorporated in the United Kingdom) Merchiston Tower, 219 Colinton Road, EDINBURGH, EH10 5DT, United Kingdom	(58) Field of Search UK CL (Edition O) C1A AVG1 INT CL ⁶ H01M 8/12 ON LINE: WPI
(72) Inventor(s) Thomas Gordon Lindsay	
(74) Agent and/or Address for Service Murgitroyd & Company 373 Scotland Street, GLASGOW, G5 8QA, United Kingdom	

(54) Solid oxide fuel cells

(57) A material for use in solid oxide fuel cells comprising a nickel-chromium oxide spinel. The material is electronically conducting and may also comprise free nickel oxide. In another embodiment of the present invention there is provided a wire for use in fuel cells wherein the wire may be surface coated, preferably by being buried within electrode material. Yet another embodiment of the invention provides a fuel cell stack wherein individual cells are connected together electrically as anode-anode and cathode-cathode pairs using porous interconnectors.

see claim¹
 may contain oxidation resistant metal Ag,
 Pt

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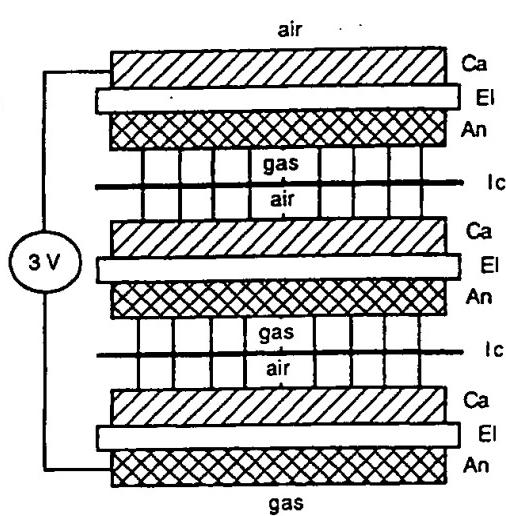


Figure 1a

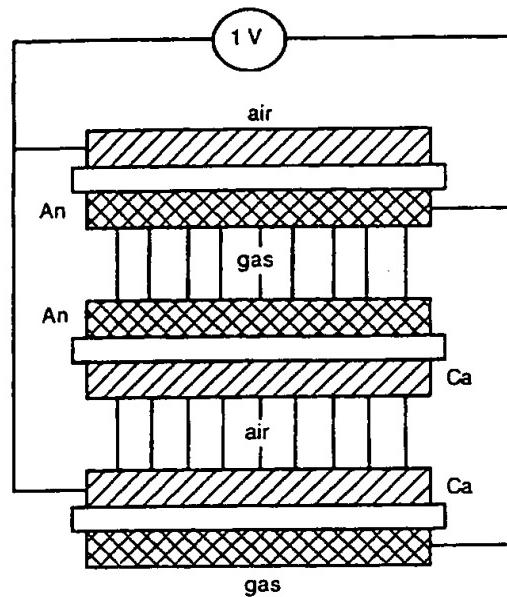


Figure 1b

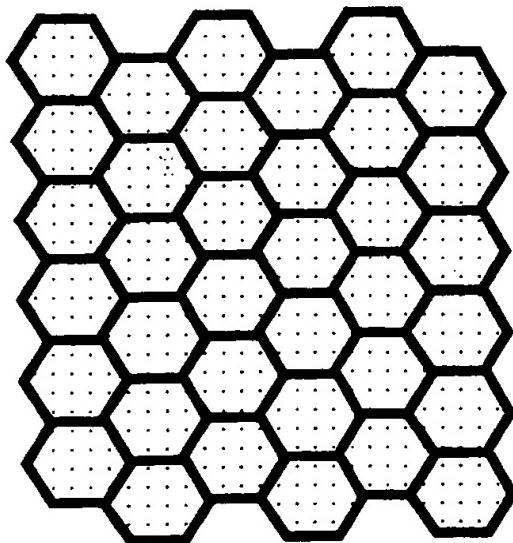


Figure 2b

Figure 2a

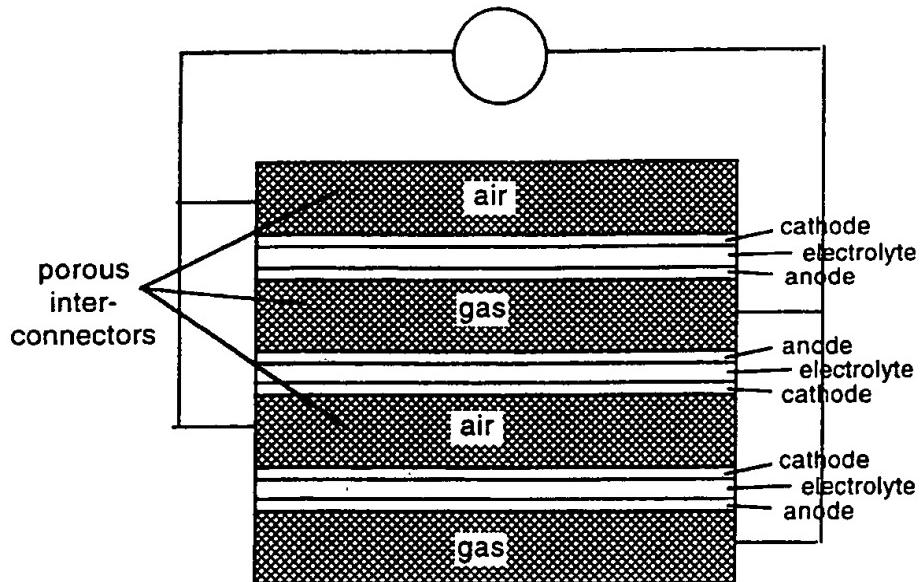


Figure 3

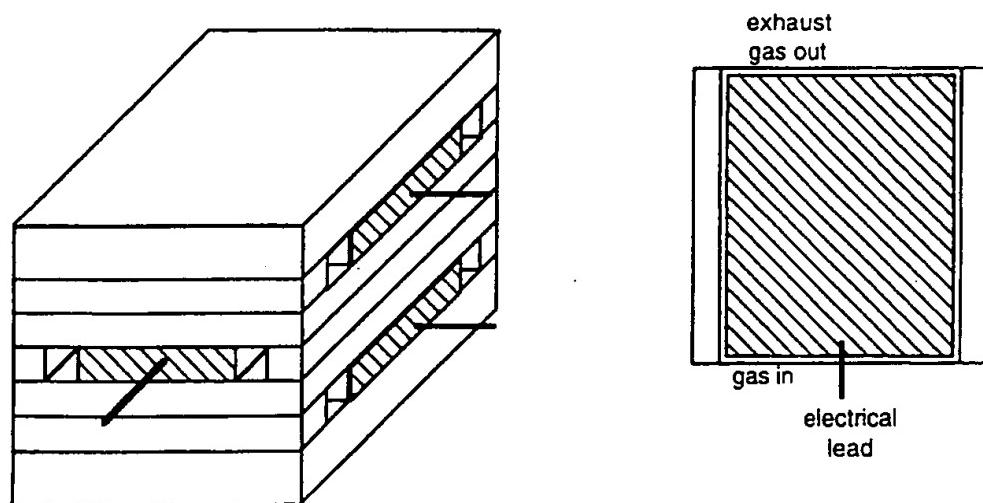


Figure 4

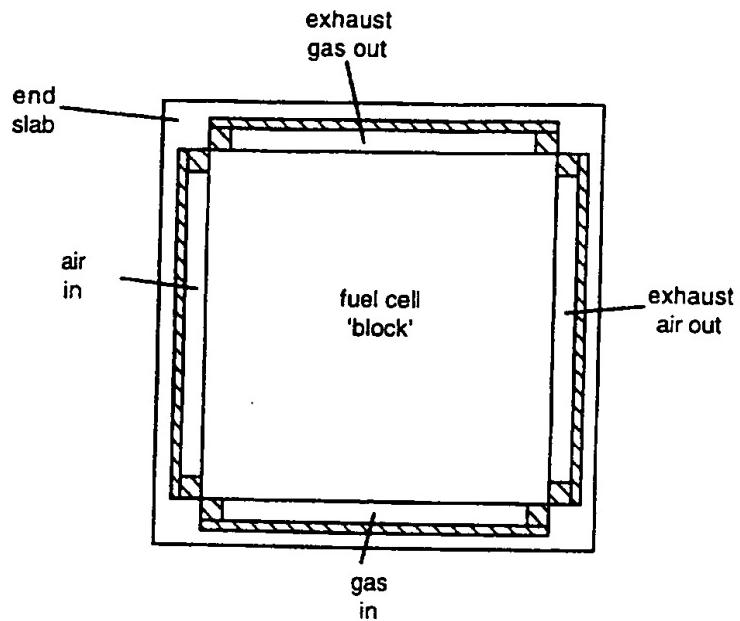


Figure 5

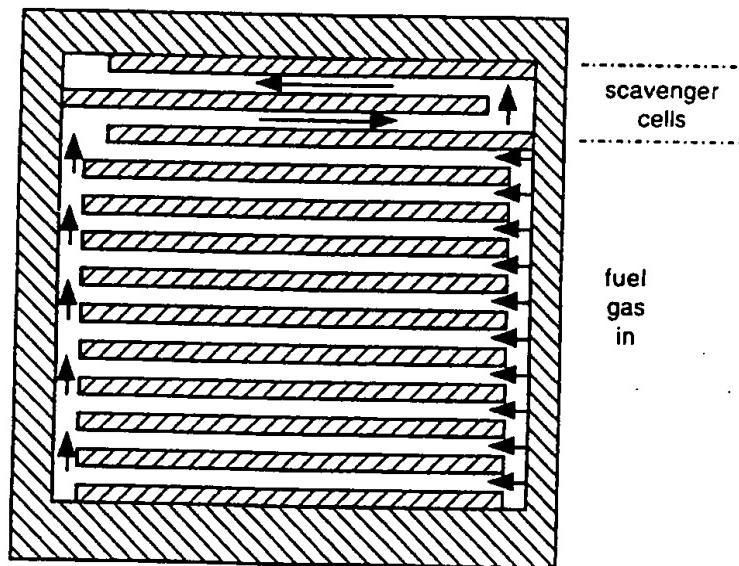


Figure 6

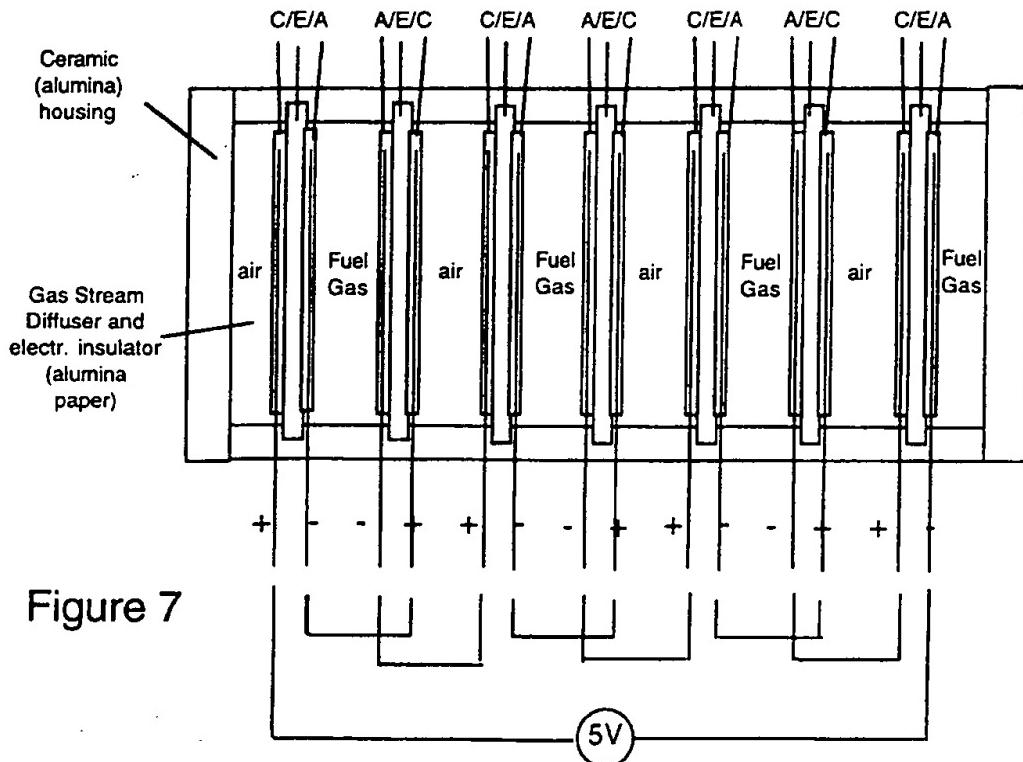


Figure 7

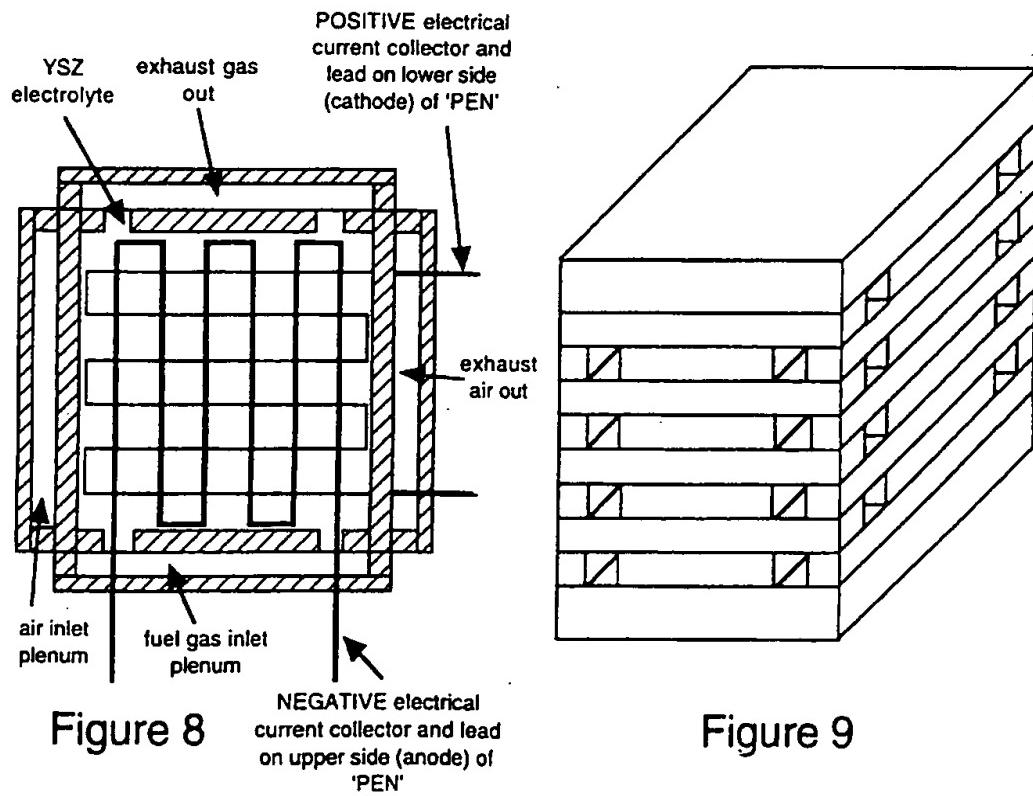


Figure 8

Figure 9

1 **"Solid Oxide Fuel Cells"**

2
3 The present invention relates to solid oxide fuel cells
4 and fuel stacks.

5
6 Fuel cell stacks and the housing thereof are employed
7 for the production of electrical power using a variety
8 of fuel gases and oxidants. There are three main stack
9 designs as follows:

10
11 1. Tubular (as manufactured by Westinghouse)
12 Advantages are ease of sealing.
13 Disadvantages are relatively low power density,
14 necessity of support tube, high cost.

15
16 2. Monolithic (as manufactured by Argonne National
17 Laboratory)
18 Advantages are high power density, 'one-piece'
19 manufacture, and moderate cost.
20 Disadvantages are sealing difficulties,
21 manufacturing without component fracture,
22 restrictions in manufacturing flexibility.

23
24 3. Planar (as manufactured by Ceramatec, Siemens etc)
25 Advantages are high power density, easier control

1 of manufacturing stages, and moderate cost.
2 Disadvantages are stack configuration complexity
3 and sealing.

4
5 Within a solid oxide fuel cell (SOFC) the cathode is
6 usually made from doped lanthanum manganite, the anode
7 from a cermet of nickel in stabilised zirconia, and the
8 interconnect is made from doped lanthanum chromite. In
9 planar SOFC the electrolyte is commonly yttria-
10 stabilised zirconia and is in plain sheet form.

11
12 A SOFC as described has the disadvantages that
13 1. The cathode material (lanthanum manganite) is
14 easily poisoned by chromium based vapours causing
15 loss of electronic conduction. These vapours
16 arise from chromium based interconnects of the
17 commonly employed corrosion resistant alloys.
18
19 2. The anode material (nickel cermet) during its life
20 in the fuel cell can see repeated cycles of
21 oxidation (to nickel oxide) and reduction back to
22 nickel, especially during warm-up and cool-down
23 conditions. The change from nickel to nickel
24 oxide (and the reverse) is accompanied by a volume
25 change, causing anode-electrolyte delamination, or
26 cracking of the electrolyte itself leading to cell
27 failure.
28
29 3. Interconnect sheet material (where used in series-
30 arranged stacks of cells) is based mainly on doped
31 lanthanum chromite. This material is extremely
32 expensive, requires excessively high firing
33 temperature for densification and possesses
34 rather poor electronic conductance. The
35 requirement for lanthanum chromite hampers many
36 conventional approaches to stack construction due

1 to its high cost and difficult (extremely high
2 temperature) processing and poor operational
3 performance.

4
5 4. The electrolyte (stabilised zirconia) has to be
6 made as thin as possible (about 20 microns) to
7 work at the reduced temperatures preferred by
8 interconnect alloys (ie 800°C as opposed to
9 1000°C). This leads to loss of strength,
10 increased fragility and considerable difficulties
11 in handling.

12
13 The present invention aims to provide improved solid
14 oxide fuel cells and fuel cell stacks.

15
16 According to one aspect of the present invention there
17 is provided a material suitable for use in fuel cells,
18 the material comprising a nickel-chromium oxide spinel
19 and being electronically conducting.

20
21 The material may further comprise free nickel oxide.

22
23 The material may further comprise oxidation resistance
24 metallic particles. Suitable particles include silver,
25 platinum, Nichrome (Trade Mark) and other oxygen
26 resistant high temperature resistant alloys.

27
28 In one embodiment the invention provides the use of the
29 material in a porous form as an anode or cathode in
30 fuel cells.

31
32 In an alternative embodiment the material may be used
33 in a dense form as an interconnect in fuel cells.

34
35 The present invention also provides an electrolyte
36 support structure, the structure comprising a thin web,

1 comprising electrolyte material.

2 In a preferred embodiment the structure comprises a
3 honeycomb wall structure of electrolyte material which
4 may be supported on a cell such as fuel cell stack
5 cell.

6 Preferably the structure is at least 15 microns thick.
7 Most preferably the structure is 25-30 microns thick
8 and is stable to operation at 800°C.
9

10 The invention further provides supported thin
11 electrolyte films.

12 Suitably the electrolyte support structure may comprise
13 stabilised zirconia or ceria-gadolinia.

14 In yet another aspect of the present invention there is
15 also provided wire for use in a solid oxide fuel cell
16 wherein the wire is surface coated.

17 The invention further provides solid oxide fuel cells
18 and solid oxide fuel cell stacks containing wires
19 wherein at least some of the wires are surface coated.

20 Preferably the wire is surface coated by being buried
21 in electrode material.

22 In particular embodiment the wires contain chromium and
23 they are coated with doped nickel chromite.

24 Alternatively, the wires may be coated with high
25 temperature oxidant resistant cobalt base brazing
26 alloys.

27 The alloy coated wires may be used in a fuel cell or

1 fuel cell stack comprising lanthanum strontium
2 manganite (LSM) cathodes wherein the coating reduces
3 migration of chromium from wire into LSM.

4
5 In one embodiment of the invention there is provided a
6 monopolar fuel cell stack comprising solid oxide fuel
7 cell wherein porous alumina is loosely sandwiched
8 between surfaces of cells.

9
10 In yet another aspect of the present invention there is
11 provided a fuel cell stack wherein individual cells are
12 connected together electrically as anode-anode pairs
13 and cathode-cathode pairs, using porous
14 interconnectors.

15
16 Preferably each fuel cell comprises a planar solid
17 electrolyte; on one side of the electrolyte a planar
18 anode; on the other side of the electrolyte a planar
19 cathode; and means for providing fluid fuels to the
20 faces of the anode and the cathode remote from the
21 electrolyte.

22
23 Preferably the electrolyte comprises stabilised
24 zirconia.

25
26 Preferably the anode comprises a porous nickel cermet.

27
28 Preferably the cathode comprises a porous lanthanum
29 manganite.

30
31 Further, according to the invention there is also
32 provided a cell stack wherein the cells are arranged
33 such that the anode of one cell faces the anode of the
34 next; the cathode of one cell faces the cathode of the
35 next, and the interconnectors are mechanically
36 sandwiched between electrode pairs.

1 Preferably the inter-connectors are actually joined to
2 the electrodes.

3 Preferably the inter-connectors are actually joined to
4 the electrodes by brazing to give improved electrical
5 contact.

7 Preferably spacer bars separate the cells.

9 Preferably the spacer bars are made of a ceramic
10 material.

12 Preferably the thickness of the spacer bars matches the
13 thickness of the interconnectors. They may be cemented
14 down to form a gas tight seal.

16

17 Examples

18 The invention is illustrated in non-limiting manner by
19 reference to the following Examples and the figures
20 wherein:

22 Figure 1a shows series connected arrangement;

23 Figure 1b shows parallel connected arrangement;

24 Figures 2a & 2b show honeycomb arrangement of the
25 electrolyte;

26 Figure 3 shows the basics of a monopolar fuel cell
27 stack;

28 Figure 4 illustrates a typical fuel cell stack;

29 Figure 5 illustrates a plan view of a manifolding
30 arrangement;

31 Figure 6 shows an arrangement whereby the exhaust fuel
32 gas is fully used up;

33 Figure 7 illustrates seven cells in a monoplanar
34 arrangement;

35 Figure 8 is a plan view of the stack as shown in Figure
36 7; and

1 Figure 9 illustrates the construction of a fuel cell
2 stack.

3

4 Example 1 relates to figures 1-4.

5

6 The operating principles of planar solid oxide fuel
7 cell stacks is indicated in Fig 1a for a series
8 connected, and Fig 1b for a parallel connected
9 arrangement. In both cases, gas is presented to the
10 anode (An), air to the cathode (Ca), and the
11 concomitant reactions via the electrolyte (El) give an
12 open circuit voltage of about 1 volt per cell. In the
13 series arrangement, this results in an open circuit
14 voltage of 3 volts, but requires an extra interconnect
15 layer (lc) to join the cathode of one cell with the
16 anode of the next, and keep the air and gas streams
17 separate. In the parallel arrangement, no interconnect
18 is used or needed, and the cells are arranged such that
19 anode faces anode, and cathode faces cathode. This
20 simplifies gas and fuel feed arrangements, but, for the
21 three cells shown, results in only one volt open
22 circuit. Irrespective of the arrangement, however, a
23 similar wattage will be delivered. The connections
24 between the cell in both arrangements are shown as
25 metallic wires, although sculpted metal plates (Siemens
26 design) or ceramic materials (lanthanum chromite) are
27 traditionally used. Only three cells are shown in each
28 arrangement, but clearly there is no limit to the
29 number of cells which may be connected together.

30

31 The invention described herein relates to solid oxide
32 fuel cells (SOFC), novel materials for use therein, the
33 design and layout of individual, or sets of, components
34 for use in SOFC.

35

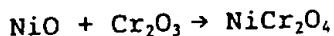
36 Due to the necessity of the cathode to tolerate

1 chromium vapour in stacks employing chromium based
2 alloys or ceramics, it was necessary to find a material
3 which would not be poisoned in a similar manner to that
4 exhibited by the conventionally used lanthanum
5 manganite. By incorporating metallic oxidation-
6 resistant particles in amounts necessary to exceed the
7 percolation density, into the spinel of the invention,
8 a highly electronic conducting cermet results. It is
9 then possible to join wires to this cermet, either by
10 embedding their ends in the material, or by brazing
11 them in place, such that low electrical resistance
12 connections can be made between cells and interconnects
13 (series stacking), and between individual cells
14 themselves (parallel stacking). Making the cermet
15 porous is the final step in producing the cathode.
16

17 This cermet has application also as an anode material,
18 the spinel part itself, unlike the traditional zirconia
19 matrix of the zirconia-nickel cermet, being
20 electronically conducting, thus promoting further
21 electrical conductance in the final spinel cermet.
22 Present drawbacks of the conventional nickel-zirconia
23 cermet are its requirement to undergo redox reactions
24 during start-up or close-down conditions. These cycle
25 the nickel to nickel oxide and back, with each change
26 accompanied by a volume change, which eventually
27 results in delamination from the electrolyte, or
28 fracture of the electrolyte. Replacing the system with
29 a cermet spinel, where the metallic network particles
30 will remain largely chemically unchanging in both the
31 oxidation or reduction conditions, will avoid the
32 corresponding dimensional changes, and deleterious
33 effects on the electrolyte. Again, the cermet needs to
34 be manufactured to be porous, to allow percolation of
35 the gases up to the electrolyte interface.
36

1 As the spinel cermet can tolerate both oxidising and
2 reducing conditions, it has potential for use as an
3 interconnect. Unlike both cathode and anode, the
4 interconnect requires to be fully dense to prevent
5 contact of the air and gas feeds (see Fig 1a - series
6 stacking arrangement).

7 Nickel-chromium oxide may be formed by mixing nickel
8 oxide and chromium oxide in equal molar ratios:
9



10 The nickel-chromium oxide may then be pressed
11 (approximately 20lb/in²) to form a disc and fired in the
12 air at approximately 1200°C.
13

14 To produce a porous form of the nickel chromium oxide
15 material, large particle starting materials may be used
16 or plastic particles may be incorporated which melt and
17 leave pores when the material is fired.
18

19 To produce a dense form of the nickel chromium oxide
20 material, finer powder starting material may be used,
21 greater pressure may be used and/or the material may be
22 fired at a higher temperature or for a longer time than
23 is necessary for the porous form.
24

25 The use of metallic materials in the stack design is
26 favoured if the operating temperature can be lowered.
27 This, unfortunately, for any given electrolyte, results
28 in slower ionic transfer, but the situation may be
29 mitigated by reducing the path length through which the
30 ions have to pass. This then requires the electrolyte
31 to be as thin as possible, with around 25 microns being
32 a suitable thickness for acceptable operation at 800°C.
33 The electrolyte has then little mechanical strength,
34 but the situation may be improved by 'encasing' it in a
35 honeycomb-wall structure of the same material. This is
36

1 illustrated in plan view in Figure 2a, with a typical
2 cross section being shown in Figure 2b. The cell walls
3 will then support the thin connecting web. The
4 'honeycomb', after firing to shape, may be 'filled'
5 with electrode material on each side, with one or more
6 connecting wires being 'attached' to each honeycomb
7 cell unit.

8
9 According to the invention the cathode can be made as a
10 cermet, and being based on an electronically conducting
11 nickel-chromium oxide (spinel), cannot be "poisoned" by
12 chromium bearing materials. Further, the introduction
13 of oxidation resistant alloy particles into this spinel
14 improves its electrical conductivity far beyond that of
15 the conventional lanthanum manganite, and also allows
16 connection of chromium bearing interconnect wires
17 directly into the cermet, or by brazing them onto the
18 cermet. Chromium bearing alloys, such as the sculpted
19 material used by Siemens, can be used in close contact
20 with the cathode without cathode poisoning effects.

21
22 A similar cermet to that described above can be used
23 for the anode. As the metallic particles in the cermet
24 are oxidation resistant, there is no expansion change
25 resulting from redox cycles. In addition, the spinel
26 matrix is electronically conducting giving improved
27 performance over the non-conducting zirconia matrix of
28 the conventional anode cermet.

29
30 The cermet spinel material used for anode and cathode,
31 can also be used, in dense form, as an interconnect,
32 giving a cheap, highly conducting, and easily processed
33 alternative to the conventionally used lanthanum
34 chromite interconnect.

35
36 The integral honeycomb-wall/web structure design allows

1 the production of supported thin electrolyte films
2 which give handleability and processability for fuel
3 cell operation at reduced temperatures. Being modular,
4 multiple units can be assembled with common gas feeds,
5 as indicated in the British Patent Application No
6 9502970.8. The stack design is sufficiently flexible
7 to allow the use of other planar cell concepts, such as
8 supported electrolyte designs for low temperature
9 operation.

10

11 Example 2

12 Example 2 relates to Figures 3, 4, 5 and 6. Figure 3
13 shows the basics of a monopolar fuel cell stack,
14 containing three active cells. All the cell components
15 are solid, and comprise a central oxygen-ion-carrying
16 electrolyte (typically stabilised zirconia), with on
17 one of its sides an anode (generally a porous nickel
18 cermet), and on its other side a cathode (typically a
19 porous lanthanum manganite). Oxygen gas (or air) is
20 presented to the cathode, becomes ionised by taking up
21 electrons, and diffuses through the electrolyte lattice
22 to the anode. Here it reacts with hydrogen gas in
23 contact with the anode, to form water, and give up its
24 electrons, thus creating a voltage difference across
25 the cell.

26

27 Figure 3 shows a method of connecting these individual
28 cells together electrically, as anode-anode pairs, and
29 cathode-cathode pairs, using porous interconnectors.
30 Wires are joined to these interconnectors as shown, and
31 supply approximately 1 volt (open circuit) at high
32 current. The arrangement may be imagined as a series
33 of batteries all connected in parallel.

34

35 Figure 4 illustrates a typical stack hardware, based on
36 the schematic of Figure 3.

1 The anode/electrolyte/cathode assembly comprising the
2 cell, is now, for simplicity, shown as one block. As
3 indicated above, these cells are arranged such that
4 anode of one cell faces the anode of the next; likewise
5 cathode faces cathode. The interconnect is
6 mechanically sandwiched between these electrode pairs,
7 and where possible actually joined to the electrode by,
8 for example, brazing to give improved electrical
9 contact.

10 As it is essential to keep the air an combustive gas
11 streams apart, the arrangement allows the gas to be
12 presented to the front face, say, and leave at the
13 opposite face, having passed through the porous
14 interconnector. The air, on the other hand is
15 presented to the face lying at 90 degrees to the face
16 used for the gas, and likewise emerges at its oppose
17 face. Spacer bars, conveniently made of ceramic
18 material, lie along the sides of the cell plate
19 assemblies, to separate them. Their thickness is
20 chosen to match the thickness of the interconnect, and
21 they are cemented down to form a gas-tight seal.
22

23 Figure 5 illustrates a plan view of a manifolding
24 arrangement, again probably of ceramic, and joined to
25 the fuel cell 'block' to form four gas-tight channels.
26 Block and channels would further be cemented to an end-
27 slab which would act to close off the channels at one
28 end, gas and air being fed in through the remaining
29 open ends. In practice, weight would be applied
30 mechanically to compress the stack, to ensure good
31 electrical contact of all the layered element. Wires
32 from each interconnector would be joined to a larger
33 conductor wire which would pass up the respective gas
34 or air channels, and pass out through seals to supply
35 the electrical power. A convenient size of stack would
36

1 be a cube of side 50mm, and would have approximately 25
2 cells, and deliver about 200 watts at 0.7 volts. These
3 building blocks would then be connected electrically in
4 series, to give higher voltage outputs, for example 18
5 connected in series would give approximately twelve
6 volts and delivering 3.6 kilowatts.

7
8 Figure 6 shows an arrangement whereby the exhaust fuel
9 gas is fully used up by passing it through two or three
10 'scavenger' cells. As these cells are supplied with
11 already depleted gas, their output will be less than
12 the 'main' cells. Even in a worst case, where one of
13 these cells is supplied with a totally exhausted gas,
14 there will be no 'shorting' effect presented to the
15 parallel arrangement, as the typical working cell
16 voltage (0.7 volts or less) will be too low to drive a
17 reverse reaction of the electrolysis of the water
18 (needlessly wasting power), to produce hydrogen. This
19 allows a degree of flexibility in the system to allow
20 for changes in fuel gas flow patters, and the effect on
21 those from varying power demands.

22
23 Example 3 relates to figure 7, 8 and 9 wherein:

24
25 Figure 7 illustrates seven cells in a monoplaner
26 arrangement.

27 Figure 8 is a plan view of the stack as shown in
28 Figure 3.

29 Figure 9 illustrates the construction of a fuel cell
30 stack.

31
32 This example relates to a compact, modular, planar SOFC
33 stack, comprising a minimum of seven, 50mm square 'PEN'
34 units, no lanthanum chromite or other interconnect, and
35 developing approximately 50 watts at 5 volts (based on
36 a current density of 0.5 amps/sq.cm.).

1 This design has been carefully engineered to give a
2 practical, easy to build, fuel cell stack, without the
3 expensive, difficult to process, and poorly performing
4 traditional lanthanum chromite interconnect. In fact,
5 as no interconnect at all is required, each PEN is
6 self-contained, and truly modular, and its performance
7 can be optimised independent of other stack elements.

8
9 Because this design uses a buried-wire-in-electrode
10 technique, in principle akin to that used for heating
11 elements encapsulated in ceramic, and because these
12 wires generally contain chromium, use may be made of a
13 porous cathode made of doped nickel chromite, a more
14 compatible material. Alternatively, surface coating of
15 these wires would allow their use with LSM cathodes,
16 the coating reducing the migration of chromium from the
17 wire into the LSM, with its resulting 'poisoning'
18 effect.

19
20 Figure 7 indicates, schematically, the arrangement
21 proposed, and shows seven PEN cells, arranged in a
22 novel manner, with the anode of one cell facing the
23 anode of the next cell, and, likewise, cathode facing
24 cathode. This allows a common gas feed to two similar
25 electrode surfaces, and considerably aids gas sealing
26 and manifolding arrangements. Porous alumina felt is
27 loosely sandwiched between each surface, and acts as a
28 gas diffuser, and electrical separator. For ease of
29 visualisation, the wire terminations or lead-outs from
30 the anode and cathode of any given PEN, are shown lying
31 in the same orientation. As shown in Figure 8, they
32 are, in fact, offset by ninety degrees. Figure 1 also
33 shows the connection strategy, in this case a cells-in-
34 series arrangement, giving about 5 volts (7×0.7
35 volts), with the cells under load. These connections
36 are made externally, and can be re-arranged at will for

1 other desired voltages. At 0.5 amps/sq.cm. of cell
2 surface, 10 amps per 'PEN' is expected, yielding a 50
3 watt output from a stack less than 3 cms high. This
4 represents an extremely high power density (0.7
5 watts/cc or 0.7 MW/m³)

6
7 Figure 8 is a plan view of the stack, with the end cap
8 removed, and shows 'PEN' with anode face upwards,
9 supported on the Yttrium, Strontium, Zirconia
10 electrolyte. Although there are many different
11 arrangements possible for current collection from the
12 electrodes, shown is a continuous wire embedded in the
13 electrodes, and co-fired with the structure. From work
14 on metallic foams at least for the nickel-chromium
15 composition available, it was shown that non-uniform
16 composition, high surface area, and localised thin
17 connection webs, led to unacceptable lifetimes in
18 oxidising atmospheres at 900°C. Commercial wire
19 compositions, on the other hand, which have been
20 designed for use as furnace windings, are available in
21 thin sections, with temperature oxidation resistance to
22 at least 1200°. Considerable scope exists within this
23 programme to optimise the pitch and wire diameter of
24 the flat winding design, in conjunction with electrode
25 thickness and electrical conductivity. It should also
26 be possible to heat the stack to working temperature by
27 powering the windings. This would need to be carried
28 out in a controlled manner to avoid thermal gradients
29 causing structural failure.

30
31 Figure 9 shows the probable construction. Again, for
32 clarity, the other walls forming the plenum chambers
33 have been removed to show the 'PEN' support housing
34 only, and the gas entry ports, out of which the current
35 collector leads are fed, and thence either up and
36 through the top plate, or individually through the

1 plenum other walls. The hidden faces of the stack have
2 an identical arrangement, and the design is contrived
3 as a cross-flow. Glass bonding, ceramic to bonding,
4 and ceramic metal seals are used in this construction.

5

6 While the invention relates particularly to solid oxide
7 fuel cells (referred to as SOFC in this document), the
8 new materials should have application to other types of
9 fuel cells (polymeric, molten, carbonate, phosphoric
10 acid etc), and also to gas sensors, especially high
11 temperature sensors.

12

1 Claims

2
3 1. A material for use in fuel cells comprising a
4 nickel-chromium oxide spinel.

5
6 2. A material as claimed in Claim 1 further comprising
7 free nickel oxide.

8
9 3. A material as claimed in Claim 1 or 2 further
10 comprising oxidation resistant metallic particles.

11
12 4. A material as claimed in claim 3 wherein the
13 oxidation resistant metal is selected from a group
14 including silver, platinum or Nichrome (Trademark).

15
16 5. A material as claimed in any preceding claim
17 wherein the material is porous.

18
19 6. An interconnect material for use in fuel cells
20 comprising a material as claimed in any of Claims 1 to
21 5.

22
23 7. A material for use as a support structure for use
24 in fuel cells comprising of a thin web of electrolyte
25 material.

26
27 8. A material as claimed in claim 7 wherein the
28 electrolyte material is of a honeycomb structure.

29
30 9. A material as claimed in Claim 7 or 8 having a
31 thickness of at least 15 microns.

32
33 10. A material as claimed in any of Claims 7 to 9
34 having a thickness of from 25 to 30 microns.

35
36 11. A material as claimed in any of Claims 7 to 10

1 comprising stabilised zirconia or ceria-gadolinia.

2

3 12. A wire for use in solid oxide fuel cells and cell
4 stacks wherein the wire is surface coated with an
5 electrode material.

6

7 13. A wire as claimed in Claim 12 wherein the wire
8 contains chromium.

9

10 14. A wire as claimed in Claim 12 or 13 wherein the
11 coating consists of doped nickel chromite.

12

13 15. A wire as claimed in Claim 12 or 13 wherein the
14 coating consists of high temperature oxidant resistant
15 cobalt base brazing alloys.

16

17 16. A fuel cell stack comprising individual fuel cells
18 wherein the individual fuel cells are connected
19 together as anode-anode and cathode-cathode pairs.

20

21 17. A fuel cell stack as claimed in claim 16 wherein
22 the connectors are porous.

23

24 18. A fuel cell stack as claimed in claim 16 or 17
25 comprising a planar solid electrolyte wherein on one
26 side of the electrolyte there is a planar anode and on
27 the other side of the electrode is a planar cathode.

28

29 19. A fuel cell stack as claimed in any of Claims 16
30 to 18 further comprising means to provide fluid fuels
31 to the faces of the anode and the cathode remote from
32 the electrolyte.

33

34 20. A fuel cell stack as claimed in any of Claims 16
35 to 19 wherein the electrolyte comprises stabilised
36 zirconia.

- 1 21. A fuel cell stack as claimed in any of Claims 16
2 to 20 wherein the anode comprises a porous nickel
3 cermet.
- 4
- 5 22. A fuel cell stack as claimed in any of Claims 16
6 to 21 wherein the cathode comprises a porous lanthanum
7 manganite.
- 8
- 9 23. A fuel cell stack as claimed in Claim 16 wherein
10 the individual cells are arranged such that the anode
11 of one cell faces the anode of the next cell; the
12 cathode of one cell faces the cathode of the next cell;
13 the interconnectors are mechanically sandwiched between
14 electrode pairs.
- 15
- 16 24. A fuel cell stack as claimed in Claim 16 or 23
17 wherein the interconnectors are joined to the
18 electrodes.
- 19
- 20 25. A fuel cell stack as claimed in Claim 24 wherein
21 the interconnectors are joined to the electrodes by
22 brazing to give improved electrical contact.
- 23
- 24 26. A fuel cell stack as claimed in Claim 25 wherein
25 spacer bars separate the cells.
- 26
- 27 27. A fuel cell stack as claimed in Claim 26 wherein
28 the spacer bars are made of a ceramic material..
- 29
- 30 28. A fuel cell stack as claimed in Claim 26 or 27
31 wherein the thickness of the spacer bars matches the
32 thickness of the interconnectors.
- 33
- 34 29. A fuel cell stack as claimed in any of Claims 26
35 to 28 wherein the spacer bars may be cemented down to
36 form a gas-tight seal.



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Claims searched: 1-6

Examiner: C.A. Clarke
Date of search: 19 December 1996

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Search Report under Section 17

Databases searched:

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UK Cl (Ed.O): C1A (AVG1)

Int Cl (Ed.6): H01M 8/12

Other: ONLINE: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB1522870 MATSUSHITA see claim 4	1
X	GB1346794 PPG see claim 14	1
Y	WO 94/09521 A FRAUNHOFER GES FOERDERUNG see Derwent Abstract	2
X	Derwent Abstract 73-68905U & JP730036297A YUASA	1,2
X	Derwent Abstract 77-31723Y & JP520036786A MATSUSHITA	1,2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.